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(54) Method for reducing waveform distortion in an electrical utility system and circuit for an electrical utility system.

(57) The invention relates to an interference suppression method and circuit for an electrical system, said electrical system comprising a main transformer (2) with a star point (12), phase leg conductors (L1, L2, L3) connected to the transformer (2), a neutral conductor (N) connected to the earth potential (3) and to the star point (12) of the transformer (2), and loads (5) connected between the phase leg conductors (L1, L2, L3) and the neutral conductor (N), said loads being connected to the neutral conductor (N) at connection points (4). In accordance with the invention a bandstop filter (1) tuned at a center frequency 3*f is connected between the star point (12) of the transformer (2) and the connection points (4) of the loads (5).

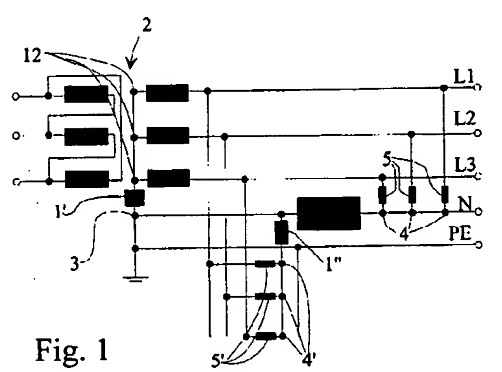

Fig. 1

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The invention relates to a method for reducing waveform distortion according to the preamble of claim 1.

The invention also concerns a circuit for use in an electrical utility system.

Nonlinear loads which do not have a sinewave input current waveform but which rather steal a current pulse with steep leading and trailing edges, generating harmonic distortion on the voltage waveform of an electrical system. Such consumers are, e.g., miniature fluorescent lamps equipped with an electronic ballast: these lamps consume a current pulse of only 1.5 ms duration at the top of the 50 Hz voltage halfwave. Moreover, in a modern office environment the electrical system may be comprehensively loaded by problematic consumers of equally low quality including computers, copiers, printers and air-conditioning equipment with electronic speed control. The dominating overtone component, namely the third harmonic, caused by such loads is summed almost arithmetically on the neutral conductor of the electrical system. In practice, almost two-fold currents have been measured on the neutral conductor with respect to the current of the phase legs. Conventionally, the neutral conductor has no overload protection, and with the steady increase of electric energy consumption, a hazard situation is imminent. Furthermore, the third harmonic of the mains frequency has been identified as a source of interference with computer equipment and communications facilities.

It is an object of the present invention to overcome the shortcomings of the above-described technology and to achieve an entirely novel method of electrical interference reduction method for electrical utility networks and a filtering circuit for use in an electrical utility network.

The invention is based on placing a bandstop filter between the star point of the main transformer and the connection points of the loads, whereby the center frequency of the filter is tuned at the third harmonic of the mains frequency.

More specifically, the method according to the invention is characterized by what is stated in the characterizing part of claim 1.

Furthermore, the circuit according to the invention is characterized by what is stated in the characterizing part of claim 5.

The invention offers significant benefits.

The method according to the invention is capable of preventing neutral conductor overloading, and furthermore, magnetic fields caused by currents in the neutral conductor can be essentially reduced. Additionally, interference with communications and computer equipment is reduced. Also power losses caused by the third harmonic component can be effectively reduced. By virtue of using a saturable magnetic steel circuit, the impedance of the filter can be made extremely low for short-circuit currents.

In the following, the invention will be examined in more detail by means of exemplifying embodiments with reference to the attached drawings, in which:

Figure 1 is a basic diagram of an electrical circuit according to the invention;

Figure 2 is the circuit diagram of a filter embodiment employed in the method according to the invention;

Figure 3 is a side view of an inductor structure suited for implementing the inductance of Fig. 2; and

Figure 4 is a graph illustrating the impedance vs. frequency characteristic of a filter configuration corresponding to that shown in Fig. 2.

With reference to Fig. 1, an electrical utility system TN-S comprises a main transformer 2 with a star point 12, phase leg conductors L1, L2 and L3, a neutral conductor N and a protective earth conductor PE. Electric energy is transferred in an electrical system using alternating current at a frequency f_0 which typically is 50 Hz in Europe and 60 Hz on the North American continent. Loads 5 and 5' are connected between the phase leg conductors L1 - L3 and the neutral conductor N. The loads 5 and 5' are connected to the neutral conductor N at connection points 4 and 4'. The neutral conductor N is further connected to the actual earth potential at an earthing point 3. According to the invention, a bandstop filter 1, 1' or 1" tuned to filter away the third harmonic of the mains frequency ($3*f_0$) is connected to the neutral conductor N between the connection point 4 (or 4') of the load 5 (or 5') and the actual earth potential 3, or between transformer star point 12 and neutral conductor N.

With reference to Fig. 2, the filter is typically formed by a series-parallel connected circuit tuned to the third harmonic of the mains frequency comprising series-connected inductance L and resistance R in parallel with capacitance C. As mentioned above, the filter resonant frequency is $3*f_0$, which is 150 Hz in Europe and 180 Hz in the USA, respectively. If the resistance R is small, the resonant frequency of the filter is approximately determined by the equation

$$1 - \omega^2 LC = 0,$$

where in a 50 Hz network $\omega = 2\pi*150$ 1/s. According to the invention, the inductor can have either an air-core, magnetic-steel core or ferrite core structure. The air gap of a magnetic-steel or ferrite core is dimensioned so as to avoid saturation of the core material at a neutral conductor current of twice the nominal phase leg current.

The inductance L is advantageously formed by a number of small, parallel-connected, magnetic steel core inductors.

Here, the total current-carrying cross section of the conductors of the parallel-connected inductors must be at least equal to the cross section of the neutral conductor. The impedance Z of the filter is

$$Z = \frac{R\cdot(1-\omega^2 LC\cdot k) + j\omega L(1+\frac{T}{T_L})}{1-\omega^2 LC + \frac{R-\omega^2 LCR_s}{R_F} + j\omega T(1+k+\frac{a}{T}+\frac{R_S}{R_F})}$$

in which

$k = \frac{R_S}{R}$, $a = \frac{L}{R_F}$, $T = RC$, $T_L = \frac{L}{R_S}$, *R_F represents iron core losses*

The eddy current losses of the inductor core increase proportional to the square of the magnetic flux frequency. To keep the Q-value of the inductor sufficiently high, the core must be made either from a ferrite material or laminated from special-grade, low-loss "electrical" sheet steel.

With reference to Fig. 3, a typical embodiment of the inductor L for the circuit of Fig. 2 is shown. The cross section of the neutral conductor is assumed to be 35 mm² for I_n = 125 A. The capacitance of the capacitor C is selected as 2.64 mF. Then, the filter circuit can be tuned to resonance at 150 Hz using an inductor L with an inductance of 0.426 mH. In practice, the width l_0 of the air gap 7 and the cross section A_{Fe} of the magnetic circuit center leg 10 determine the first approximation of the inductance of one inductor of the filter according to the equation

$$L = \mu_0 N^2 \frac{A_{Fe}}{l_0}$$

where N is the number of turns in the inductor winding and μ_0 is the permeability of vacuum (1.256 μH/m).

In this case the air gap l_0 has a value of 7.6 mm when the number of turns N is 116 and the cross section of the inductor center leg 10 is 10.9 cm².

In the inductor assembly, the E-shaped magnetic steel core laminations 8 are trimmed such that the center legs are shorter by half the air gap, that is, $l_0/2$ = 3.8 mm. Hence, when two identical laminated stacks 8 are juxtaposed, the total air gap 7 will be 7.6 mm as desired.

A winding of 116 turns is wound about the center leg 10 using copper wire of dia. 3.0 mm. To make the total cross section of the winding conductors more than 35 mm², i.e. more than the cross section of the neutral conductor, e.g., ten inductor windings can be connected in parallel. The winding form 9 is compressed between the laminated core halves 8 during the assembly of the inductor.

With reference to Fig. 4, the filter impedance reaches its maximum value of 10 ohm at the 150 Hz center frequency and the filter impedance falls below 0.15 ohm at 50 Hz.

Next, the magnetic circuit must be checked not to saturate at the current level of 250 A in the neutral conductor N of a 50 Hz electrical system. Then, the current through each winding of a single inductor is I = 1/10 * 250 A = 25 A.

The peak value of the magnetic flux and the magnetic induction is computed

$$LI = N\Phi = N\cdot\frac{\hat{b}}{\sqrt{2}}\cdot A_{Fe}$$

$$\hat{b} = \frac{4.26\cdot 25\cdot\sqrt{2}\cdot 10^{-3} Vs}{116\cdot 10.34\cdot 10^{-4} m^2} = 1.26T$$

If the magnetic core of the inductor of filter 1 is driven to saturation, harmonics will be generated in the electrical system.

In the following the saturation of the magnetic circuit is checked with computer loads, which can exeed 40 V at the third harmonic (e.g. 150 Hz).

$$U = N\omega\frac{\hat{b}}{\sqrt{2}}A_{Fe}$$

$$\hat{b}(150Hz) = \frac{40\sqrt{2}V}{116\cdot 300\pi\frac{1}{s}\cdot 10.34\cdot 10^{-4}m^2} = 0.50T$$

The arithmetic sum of the the 50 Hz (or 60 Hz) iduction and 150 Hz (or 180 Hz) induction has an effect on the saturation of the magnetic core.

However, the saturation of the magnetic core at short-circuit current levels has the benefit that the reactance of the filter is reduced to a fraction of its normal value approaching that of an air-core inductor. Then, the fuse protection of the system is quickly tripped in the short-circuit situation, whereby harmonics generated on the neutral conductor N during a period of less than a second cause no harm in the system.

A 50 Hz unbalanced current flowing through the third harmonic filter in accordance with the invention causes a movement of the zero point of phase voltages. The filter should be dimensioned such that this movement of the zero point is less than 8 % of the phase voltage. In other words the inductance of the filter should be dimensioned at 50 Hz below a certain value. This rule can be presented as an equation:

$$L_{max} = \frac{0.08\cdot\frac{8}{9}U_n}{\sqrt{3}\cdot 100\pi\cdot I_N}$$

Further, the third harmonic filter in accordance with the invention should be dimensioned such that the product of the current in the neutral conductor and the impedance of the filter at 150 Hz are at least equal to the total interference voltage at 150 Hz.

Claims

1. An interference suppression method for an electrical system, said electrical system comprising a main transformer (2) with a star point (12), phase leg conductors (L1, L2, L3) connected to the transformer (2) and a neutral conductor (N) which at its one end (3) is connected to the earth potential (3) and the star point (12) of the transformer (2) and at its other end (4) to loads (5), in which electrical system electric energy is transferred at a frequency f,

   characterized in that

   - a bandstop filter (1) tuned at a center fre-

quency 3*f is connected between the star point (12) of the transformer (2) and the connection points (4) of the loads (5).

2. A method as defined in claim 1, **characterized** in that the bandstop filter (1) tuned at a center frequency 3*f is connected between the earth potential connection point (3) of the neutral conductor (N) and the connection points (4) of the loads (5).

3. A method as defined in claim 1 or 2, **characterized** in that the bandstop filter (1) is formed by a parallel-resonant circuit.

4. A method as defined in claim 3, **characterized** in that the inductance (L) of said parallel-resonant circuit is formed by an inductor with a magnetic steel or ferrite core whose air gap is dimensioned so as to avoid saturation of the inductor magnetic circuit (8) at a neutral conductor a 50 Hz current of twice the nominal phase leg current when at the same time there is a third harmonic voltage (40 V) over the filter.

5. A circuit for an electrical system, said electrical system comprising
   - a main transformer (2) with a star point (12),
   - phase leg conductors (L1, L2, L3) connected to the transformer (2),
   - a neutral conductor (N) connected to the earth potential (3) and to the star point (12) of the transformer (2), and
   - loads (5) connected between the phase leg conductors (L1, L2, L3) and the neutral conductor (N), said loads being connected to the neutral conductor (N) at connection points (4),

   characterized in that

   - a bandstop filter (1) tuned at a center frequency 3*f is connected between the star point (12) of the transformer (2) and the connection points (4) of the loads (5).

6. A circuit as defined in claim 5, **characterized** in that the bandstop filter (1) tuned at a center frequency 3*f is connected between the earth potential connection point (3) of the neutral conductor (N) and the connection points (4) of the loads (5).

7. A circuit as defined in claim 5 or 6, **characterized** in that the bandstop filter (1) is formed by a parallel-resonant circuit.

8. A circuit as defined in claim 7, **characterized** in that the inductance (L) of said parallel-resonant circuit is formed by an inductor with a magnetic steel or ferrite core whose air gap is dimensioned so as to avoid saturation of the inductor magnetic circuit (8) at a neutral conductor a 50 Hz current of twice the nominal phase leg current when at the same time there is a third harmonic voltage (40 V) over the filter.

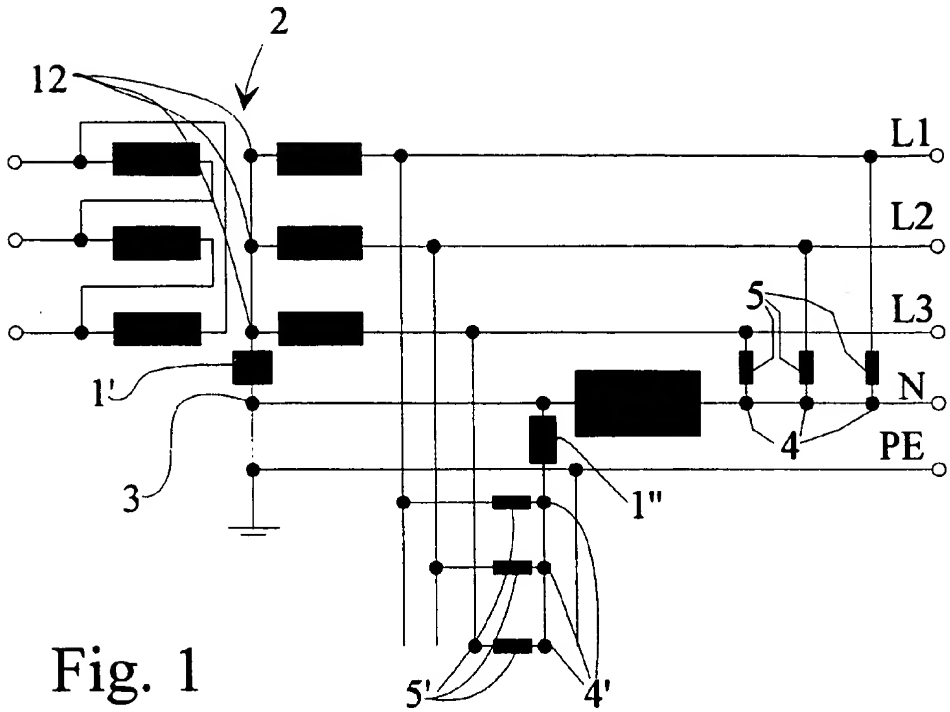

Fig. 1

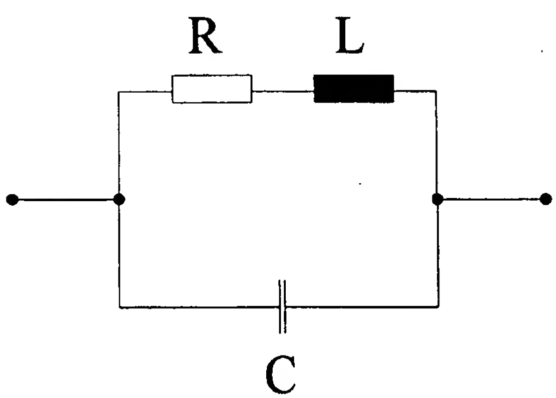

Fig. 2

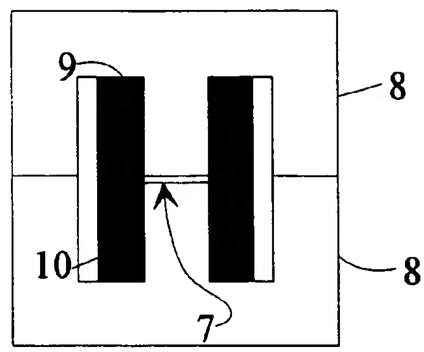

Fig. 3

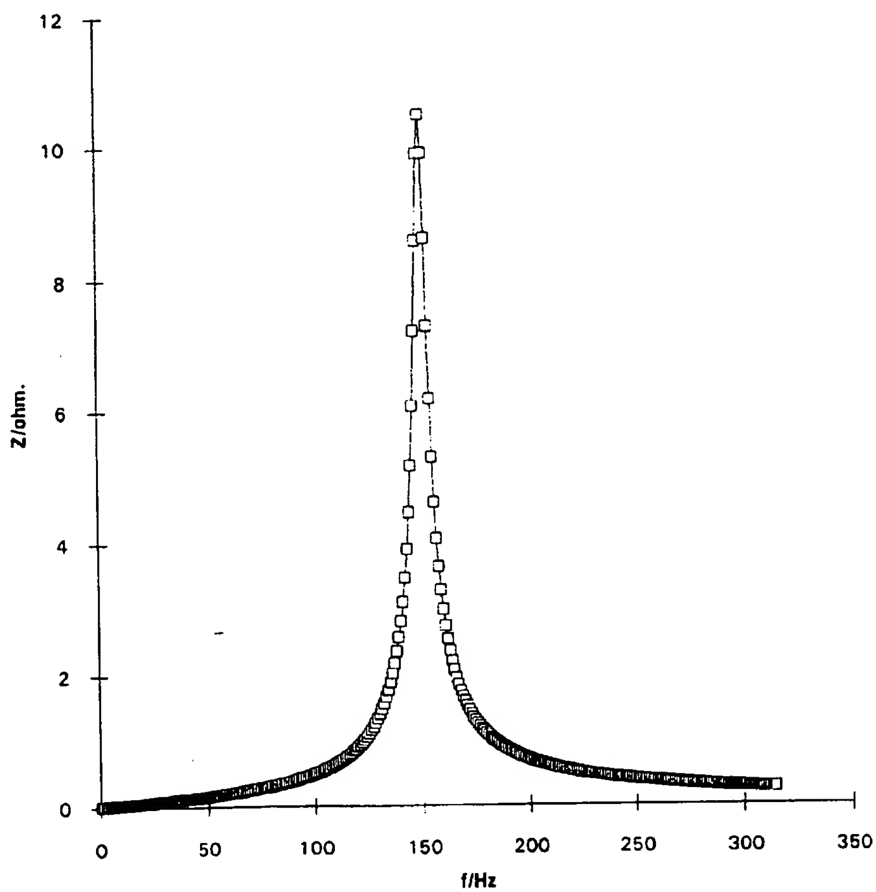

Fig. 4

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EUROPEAN SEARCH REPORT

Application Number EP 95401168.0

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 6)
A	DE - A - 4 219 214 (STN SYSTEMTECHNIK) * Column 3, line 49 - column 4, line 2 * --	1,5	H 02 J 3/01 H 03 H 7/01 H 02 M 5/18
A	EP - A - 0 187 312 (BBC) * Page 1, line 18 - page 2, line 18; claim 1 * ----	1,5	
			TECHNICAL FIELDS SEARCHED (Int. Cl.6)
			H 02 J H 03 H H 02 M

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	08-09-1995	MEHLMAUER

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
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(22) Date of filing: **19.05.1995**

(54) Method for reducing waveform distortion in an electrical utility system and circuit for an electrical utility system

Methode zur Reduzierung der Verzerrung der Wellenform in einer elektrischen Einrichtung und Schaltung für eine elektrische Einrichtung

Méthode pour la réduction de la distorsion de la forme de l'onde en un dispositif éléctrique et circuit pour un dispositif électrique

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(56) References cited:
EP-A- 0 187 312 **DE-A- 4 219 214**

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Description

The invention relates to a method for reducing waveform distortion according to the preamble of claim 1.

The invention also concerns a circuit for use in an electrical utility system.

Nonlinear loads which do not have a sinewave input current waveform but which rather steal a current pulse with steep leading and trailing edges, generating harmonic distortion on the voltage waveform of an electrical system. Such consumers are, e.g., miniature fluorescent lamps equipped with an electronic ballast: these lamps consume a current pulse of only 1.5 ms duration at the top of the 50 Hz voltage halfwave. Moreover, in a modern office environment the electrical system may be comprehensively loaded by problematic consumers of equally low quality including computers, copiers, printers and air-conditioning equipment with electronic speed control. The dominating overtone component, namely the third harmonic, caused by such loads is summed almost arithmetically on the neutral conductor of the electrical system. In practice, almost two-fold currents have been measured on the neutral conductor with respect to the current of the phase legs. Conventionally, the neutral conductor has no overload protection, and with the steady increase of electric energy consumption, a hazard situation is imminent. Furthermore, the third harmonic of the mains frequency has been identified as a source of interference with computer equipment and communications facilities.

It is an object of the present invention to overcome the shortcomings of the above-described technology and to achieve an entirely novel method of electrical interference reduction method for electrical utility networks and a filtering circuit for use in an electrical utility network.

The invention is based on placing a bandstop filter between the star point of the main transformer and the connection points of the loads, whereby the center frequency of the filter is tuned at the third harmonic of the mains frequency.

More specifically, the method according to the invention is characterized by what is stated in the characterizing part of claim 1.

Furthermore, the circuit according to the invention is characterized by what is stated in the characterizing part of claim 5.

The invention offers significant benefits.

The method according to the invention is capable of preventing neutral conductor overloading, and furthermore, magnetic fields caused by currents in the neutral conductor can be essentially reduced. Additionally, interference with communications and computer equipment is reduced. Also power losses caused by the third harmonic component can be effectively reduced. By virtue of using a saturable magnetic steel circuit, the impedance of the filter can be made extremely low for short-circuit currents.

In the following, the invention will be examined in more detail by means of exemplifying embodiments with reference to the attached drawings, in which:

Figure 1 is a basic diagram of an electrical circuit according to the invention;

Figure 2 is the circuit diagram of a filter embodiment employed in the method according to the invention;

Figure 3 is a side view of an inductor structure suited for implementing the inductance of Fig. 2; and

Figure 4 is a graph illustrating the impedance vs. frequency characteristic of a filter configuration corresponding to that shown in Fig. 2.

With reference to Fig. 1, an electrical utility system TN-S comprises a main transformer 2 with a star point 12, phase leg conductors L1, L2 and L3, a neutral conductor N and a protective earth conductor PE. Electric energy is transferred in an electrical system using alternating current at a frequency f_0 which typically is 50 Hz in Europe and 60 Hz on the North American continent. Loads 5 and 5' are connected between the phase leg conductors L1 - L3 and the neutral conductor N. The loads 5 and 5' are connected to the neutral conductor N at connection points 4 and 4'. The neutral conductor N is further connected to the actual earth potential at an earthing point 3. According to the invention, a bandstop filter 1, 1' or 1" tuned to filter away the third harmonic of the mains frequency (3^*f_0) is connected to the neutral conductor N between the connection point 4 (or 4') of the load 5 (or 5') and the actual earth potential 3, or between transformer star point 12 and neutral conductor N.

With reference to Fig. 2, the filter is typically formed by a series-parallel connected circuit tuned to the third harmonic of the mains frequency comprising series-connected inductance L and resistance R in parallel with capacitance C. As mentioned above, the filter resonant frequency is 3^*f_0, which is 150 Hz in Europe and 180 Hz in the USA, respectively. If the resistance R is small, the resonant frequency of the filter is approximately determined by the equation

$$1-\omega^2 LC=0,$$

where in a 50 Hz network $\omega = 2\pi^*150$ 1/s. According to the invention, the inductor can have either an air-core, magnetic-steel core or ferrite core structure. The air gap of a magnetic-steel or ferrite core is dimensioned so as to avoid saturation of the core material at a neutral conductor current of twice the nominal phase leg current. The inductance L is advantageously formed by a number of small, parallel-connected, magnetic steel

core inductors. Here, the total current-carrying cross section of the conductors of the parallel-connected inductors must be at least equal to the cross section of the neutral conductor. The impedance Z of the filter is

$$Z=\frac{R\cdot(1-\omega^2LC\cdot k)+j\omega L(1+\frac{T}{T_L})}{1-\omega^2LC+\frac{R\cdot\omega^2LCR_s}{R_F}+j\omega T(1+k+\frac{a}{T}+\frac{R_S}{R_F})}$$

in which

$$k=\frac{R_S}{R},\ a=\frac{L}{R_F},\ T=RC,\ T_L=\frac{L}{R_S},$$

R_F represents iron core losses

The eddy current losses of the inductor core increase proportional to the square of the magnetic flux frequency. To keep the Q-value of the inductor sufficiently high, the core must be made either from a ferrite material or laminated from special-grade, low-loss "electrical" sheet steel.

With reference to Fig. 3, a typical embodiment of the inductor L for the circuit of Fig. 2 is shown. The cross section of the neutral conductor is assumed to be 35 mm^2 for I_n = 125 A. The capacitance of the capacitor C is selected as 2.64 mF. Then, the filter circuit can be tuned to resonance at 150 Hz using an inductor L with an inductance of 0.426 mH. In practice, the width l_0 of the air gap 7 and the cross section A_{Fe} of the magnetic circuit center leg 10 determine the first approximation of the inductance of one inductor of the filter according to the equation

$$L=\mu_0N^2\frac{A_{Fe}}{l_0}$$

where N is the number of turns in the inductor winding and μ_0 is the permeability of vacuum (1.256 μH/m).

In this case the air gap l_0 has a value of 7.6 mm when the number of turns N is 116 and the cross section of the inductor center leg 10 is 10.9 cm^2.

In the inductor assembly, the E-shaped magnetic steel core laminations 8 are trimmed such that the center legs are shorter by half the air gap, that is, $l_0/2$ = 3.8 mm. Hence, when two identical laminated stacks 8 are juxtaposed, the total air gap 7 will be 7.6 mm as desired.

A winding of 116 turns is wound about the center leg 10 using copper wire of dia. 3.0 mm. To make the total cross section of the winding conductors more than 35 mm^2, i.e. more than the cross section of the neutral conductor, e.g., ten inductor windings can be connected in parallel. The winding form 9 is compressed between the laminated core halves 8 during the assembly of the inductor.

With reference to Fig. 4, the filter impedance reaches its maximum value of 10 ohm at the 150 Hz center frequency and the filter impedance falls below 0.15 ohm at 50 Hz.

Next, the magnetic circuit must be checked not to saturate at the current level of 250 A in the neutral conductor N of a 50 Hz electrical system. Then, the current through each winding of a single inductor is I = 1/10 * 250 A = 25 A.

The peak value of the magnetic flux and the magnetic induction is computed

$$LI=N\Phi=N\cdot\frac{\hat{b}}{\sqrt{2}}\cdot A_{Fe}$$

$$\hat{b}=\frac{4.26\cdot 25\cdot\sqrt{2}\cdot 10^{-3}\,Vs}{116\cdot 10.34\cdot 10^{-4}\,m^2}=1.26\,T$$

If the magnetic core of the inductor of filter 1 is driven to saturation, harmonics will be generated in the electrical system.

In the following the saturation of the magnetic circuit is checked with computer loads, which can exeed 40 V at the third harmonic (e.g. 150 Hz).

$$U=N\omega\frac{\hat{b}}{\sqrt{2}}A_{Fe}$$

$$\hat{b}(150Hz)=\frac{40\sqrt{2}\,V}{116\cdot 300\pi\frac{1}{s}\cdot 10.34\cdot 10^{-4}\,m^2}=0.50\,T$$

The arithmetic sum of the the 50 Hz (or 60 Hz) iduction and 150 Hz (or 180 Hz) induction has an effect on the saturation of the magnetic core.

However, the saturation of the magnetic core at short-circuit current levels has the benefit that the reactance of the filter is reduced to a fraction of its normal value approaching that of an air-core inductor. Then, the fuse protection of the system is quickly tripped in the short-circuit situation, whereby harmonics generated on the neutral conductor N during a period of less than a second cause no harm in the system.

A 50 Hz unbalanced current flowing through the third harmonic filter in accordance with the invention causes a movement of the zero point of phase voltages. The filter should be dimensioned such that this movement of the zero point is less than 8 % of the phase voltage. In other words the inductance of the filter should be dimensioned at 50 Hz below a certain value. This rule can be presented as an equation:

$$L_{max} = \frac{0.08 \cdot \frac{8}{9} U_n}{\sqrt{3} \cdot 100\pi \cdot I_N}$$

Further, the third harmonic filter in accordance with the invention should be dimensioned such that the product of the current in the neutral conductor and the impedance of the filter at 150 Hz are at least equal to the total interference voltage at 150 Hz.

Claims

1. An interference suppression method for an electrical system, including the steps of providing an electrical system comprising a main transformer (2) with a star point (12), phase leg conductors (L1, L2, L3) connected to the transformer (2) and a neutral conductor (N) which at its one end (3) is connected to the earth potential (3) and the star point (12) of the transformer (2) and at its other end (4) to loads (5), in which electrical system electric energy is transferred at a frequency f, said method being **characterized** by providing

   - a bandstop filter (1) tuned at a center frequency 3*f connected between the star point (12) of the transformer (2) and the connection points (4) of the loads (5).

2. A method as defined in claim 1, **characterized** in that the bandstop filter (1) tuned at a center frequency 3*f is connected between the earth potential connection point (3) of the neutral conductor (N) and the connection points (4) of the loads (5).

3. A method as defined in claim 1 or 2, **characterized** in that the bandstop filter (1) is formed by a parallel-resonant circuit.

4. A method as defined in claim 3, **characterized** in that the inductance (L) of said parallel-resonant circuit is formed by an inductor with a magnetic steel or ferrite core whose air gap is dimensioned so as to avoid saturation of the inductor magnetic circuit (8) at a neutral conductor a 50 Hz current of twice the nominal phase leg current when at the same time there is a third harmonic voltage (40 V) over the filter.

5. A circuit for an electrical system, said electrical system which transfers electrical energy at a frequency f comprising

   - a main transformer (2) with a star point (12),
   - phase leg conductors (L1, L2, L3) connected to the transformer (2),
   - a neutral conductor (N) connected to the earth potential (3) and to the star point (12) of the transformer (2), and
   - loads (5) connected between the phase leg conductors (L1, L2, L3) and the neutral conductor (N), said loads being connected to the neutral conductor (N) at connection points (4),

   characterized in that

   - a bandstop filter (1) tuned at a center frequency 3*f is connected between the star point (12) of the transformer (2) and the connection points (4) of the loads (5).

6. A circuit as defined in claim 5, **characterized** in that the bandstop filter (1) tuned at a center frequency 3*f is connected between the earth potential connection point (3) of the neutral conductor (N) and the connection points (4) of the loads (5).

7. A circuit as defined in claim 5 or 6, **characterized** in that the bandstop filter (1) is formed by a parallel-resonant circuit.

8. A circuit as defined in claim 7, **characterized** in that the inductance (L) of said parallel-resonant circuit is formed by an inductor with a magnetic steel or ferrite core whose air gap is dimensioned so as to avoid saturation of the inductor magnetic circuit (8) at a neutral conductor a 50 Hz current of twice the nominal phase leg current when at the same time there is a third harmonic voltage (40 V) over the filter.

Patentansprüche

1. Störungsunterdrückungsverfahren für eine elektrische Einrichtung, mit den Verfahrensschritten:

   Bereitstellen einer elektrischen Einrichtung, die einen Haupttransformator (2) mit einem Sternpunkt (12), Phasenschenkelleiter (L1, L2, L3), die an den Transformator (2) angeschlossen sind, und einen Nulleiter (N) aufweist, der mit seinem einen Ende (3) an Erdpotential (3) und an den Sternpunkt (12) des Transformators (2) und mit seinem anderen Ende (4) an Lastwiderstände (5) angeschlossen ist, wobei von der elektrischen Einrichtung elektrische Energie mit einer Frequenz f übertragen wird, das Verfahren **gekennzeichnet durch**
   Bereitstellen einer auf eine Mittenfrequenz 3*f abgestimmten Bandsperre (1), die zwischen

den Sternpunkt (12) des Transformators (2) und die Anschlußstellen (4) der Lastwiderstände (5) geschaltet wird.

2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß die auf eine Mittenfrequenz 3*f abgestimmte Bandsperre (1) zwischen die Erdpotential-Anschlußstelle (3) des Nulleiters (N) und die Anschlußstellen (4) der Lastwiderstände (5) geschaltet wird.

3. Verfahren nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß die Bandsperre (1) von einem Parallelschwingkreis gebildet wird.

4. Verfahren nach Anspruch 3, dadurch gekennzeichnet, daß die Induktivität (L) des Parallelschwingkreises mittels einer Induktionsspule mit einem Kern aus magnetischem Stahl oder Ferrit gebildet wird, wobei der Luftspalt des Kerns derart dimensioniert wird, daß Sättigung des magnetischen Induktionsspulenschaltkreises (8) bei einem 50 Hz Nulleiterstrom von zweimal dem Phasenschenkel-Nennstrom vermieden wird, während gleichzeitig eine dritte harmonische Spannung (40 V) über der Sperre abfällt.

5. Schaltkreis für eine elektrische Einrichtung, wobei die elektrische Einrichtung, die elektrische Energie mit einer Frequenz f überträgt,

einen Haupttransformator (2) mit einem Sternpunkt (12),
Phasenschenkelleiter (L1, L2, L3), die mit dem Transformator (2) verbunden sind,
einen Nulleiter (N), der mit Erdpotential (3) und dem Sternpunkt (12) des Transformators (2) verbunden ist, und
Lastwiderstände (5) aufweist, die zwischen den Phasenschenkelleitern (L1, L2, L3) und dem Nulleiter (N) geschaltet sind, wobei die Lastwiderstände mit dem Nulleiter (N) an Anschlußstellen (4) verbunden sind, **dadurch gekennzeichnet,**
daß eine auf eine Mittenfrequenz 3*f abgestimmte Bandsperre (1) zwischen dem Sternpunkt (12) des Transformators (2) und den Anschlußstellen (4) der Lastwiderstände (5) geschaltet ist.

6. Schaltkreis nach Anspruch 5, dadurch gekennzeichnet, daß die auf eine Mittenfrequenz 3*f abgestimmte Bandsperre (1) zwischen der Erdpotential-Anschlußstelle (3) des Nulleiters (N) und den Anschlußstellen (4) der Lastwiderstände (5) geschaltet ist.

7. Schaltkreis nach Anspruch 5 oder 6, dadurch gekennzeichnet, daß die Bandsperre von einem Parallelschwingkreis gebildet ist.

8. Schaltkreis nach Anspruch 7, dadurch gekennzeichnet, daß die Induktivität (L) des Parallelschwingkreises mittels einer Induktionsspule mit einem Kern aus magnetischem Stahl oder Ferrit gebildet ist, wobei der Luftspalt des Kerns derart dimensioniert ist, daß Sättigung des magnetischen Induktionsspulenschaltkreises (8) bei einem 50 Hz Nulleiterstrom von zweimal dem Phasenschenkel-Nennstrom vermieden wird, während gleichzeitig eine dritte harmonische Spannung (40 V) über der Sperre abfällt.

Revendications

1. Procédé d'élimination des parasites pour un système électrique, comprenant les étapes de présence d'un système électrique comprenant un transformateur principal (2) ayant un point étoile (12), des conducteurs de branche de phase (L1, L2, L3) reliés au transformateur (2) et un conducteur neutre (N) qui est relié, par une extrémité (3) au potentiel de la terre (3) et au point étoile (12) du transformateur (2) et, par son autre extrémité (4) à des charges (5), auxquelles est transférée, à une fréquence f, l'énergie électrique du système électrique, ledit procédé étant caractérisé par la présence

- d'un filtre coupe-bande (1) accordé à une fréquence centrale 3*f et monté entre le point étoile (12) du transformateur (2) et les points de raccordement (4) des charges (5).

2. Procédé selon la revendication 1, caractérisé en ce que le filtre coupe-bande (1), accordé à une fréquence centrale 3*f, est monté entre le point de connexion du potentiel de terre (3) du conducteur neutre (N) et les points de raccordement (4) des charges (5).

3. Procédé selon la revendication 1 ou 2, caractérisé en ce que le filtre coupe-bande (1) est formé par un circuit résonnant parallèle.

4. Procédé selon la revendication 3, caractérisé en ce que l'inductance (L) dudit circuit résonnant parallèle est formée par une bobine d'inductance ayant un noyau en ferrite ou en acier à circuits magnétiques, dont l'entrefer est dimensionné de manière à éviter une saturation du circuit magnétique de bobine d'inductance (8) au niveau d'un conducteur neutre à un courant à 50 Hz, représentant deux fois le courant nominal de la branche de phase, lorsqu'il y a en même temps une tension de troisième harmonique (40 V) sur le filtre.

5. Circuit pour un système électrique, ledit système électrique, qui transmet de l'énergie électrique à une fréquence f, comprenant :

- un transformateur principal (2) ayant un point étoile (12),
- des conducteurs de branche de phase (L1, L2, L3) reliés au transformateur (2),
- un conducteur neutre (N), relié au potentiel de la terre (3) et au point étoile (12) du transformateur (2), et
- des charges (5), reliées entre les conducteurs de branche de phase (L1, L2, L3) et le conducteur neutre (N), lesdites charges étant reliées au conducteur neutre (N) en des points de raccordement (4),

caractérisé en ce que

- un filtre coupe-bande (1), accordé à une fréquence centrale 3*f, est monté entre le point étoile (12) du transformateur (2) et les points de raccordement (4) des charges (5).

6. Circuit selon la revendication 5, caractérisé en ce que le filtre coupe-bande (1), accordé à une fréquence centrale 3*f, est monté entre le point de connexion du potentiel de terre (3) du conducteur neutre (N) et les points de raccordement (4) des charges (5).

7. Circuit selon la revendication 5 ou 6, caractérisé en ce que le filtre coupe-bande (1) est formé par un circuit résonnant parallèle.

8. Circuit selon la revendication 7, caractérisé en ce que l'inductance (L) dudit circuit résonnant parallèle est formée par une bobine d'inductance ayant un noyau en ferrite ou en acier à circuits magnétiques, dont l'entrefer est dimensionné de manière à éviter une saturation du circuit magnétique de bobine d'inductance (8) au niveau d'un conducteur neutre à un courant à 50 Hz, représentant deux fois le courant nominal de la branche de phase, lorsqu'il y a en même temps une tension de troisième harmonique (40 V) sur le filtre.

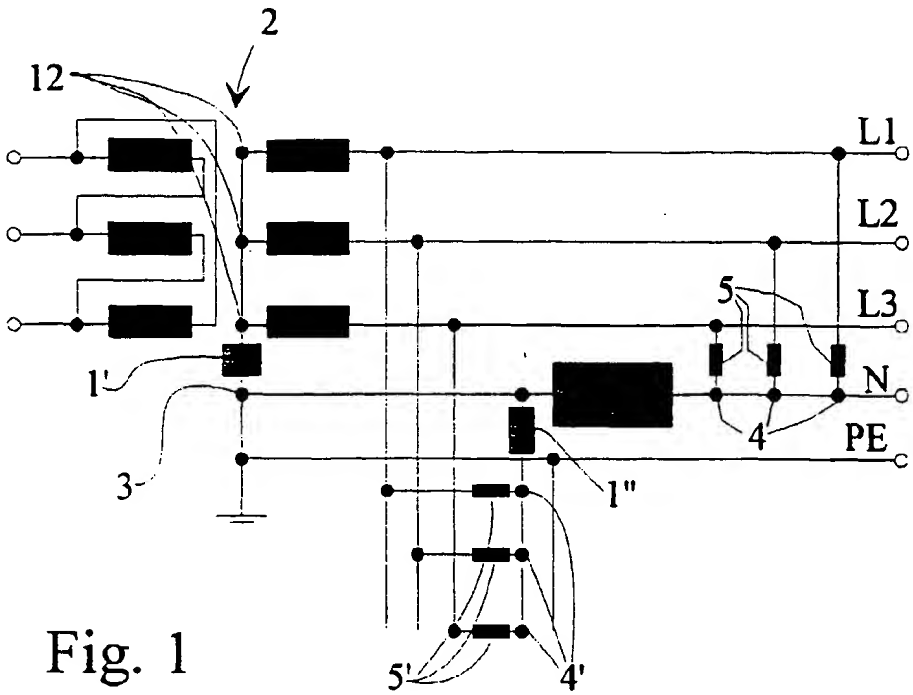

Fig. 1

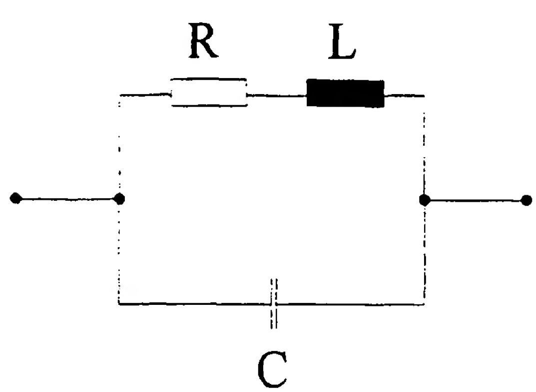

Fig. 2

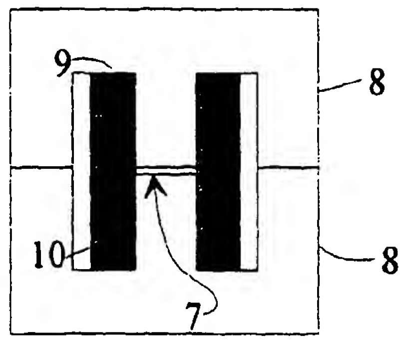

Fig. 3

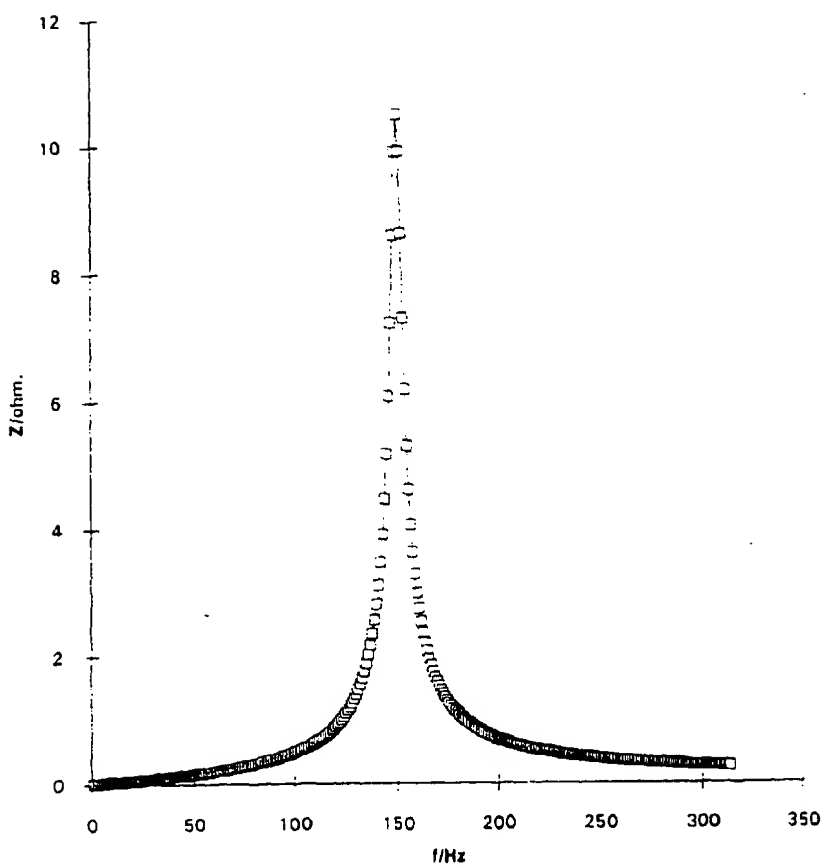

Fig. 4

PATENT SPECIFICATION

DRAWINGS ATTACHED

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Index at acceptance:—H1 T(1F, 7A8, 7C1A, 7C1B1, 7C3, 7C5, 9)

Int. Cl.:—H 01 f 31/00

COMPLETE SPECIFICATION

Improvements in or relating to Electrical Transformers

We, INTERNATIONAL BUSINESS MACHINES CORPORATION, a Corporation organized and existing under the laws of the State of New York in the United States of America, of 590 Madison Avenue, New York 22, State of New York, United States of America (assignees of COMPAGNIE IBM FRANCE) do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to electrical transformers and to methods of producing such transformers.

Transformers according to the present invention are simple in construction and may be employed in any application in which they are subjected only to relatively low-strength electric current. Apart from the simplicity of their manufacture, transformers according to the present invention possess several advantages over transformers of the prior art; in accordance with this invention it is possible, for example, to produce a core-less transformer having a transformer ratio substantially equal to 1, and to incorporate in the transformer an electrostatic screen which is practically perfect.

According to a first aspect of the present invention, an electrical transformer comprises a conductor wire constituting a primary circuit of the transformer and covered by a plurality of alternately insulating and conducting layers, one of the conducting layers constituting a secondary circuit of the transformer and the length of the layers being such that the ends of the conductor wire and the ends of each conducting layer are exposed to facilitate the fixing of electrical connections thereto.

Preferably a conducting layer between the conductor wire and said one conducting layer constitutes an electrostatic screen.

According to a second aspect of the present invention, a method of producing a transformer according to said first aspect comprises suspending the conductor wire in a first bath with the ends of the wire exposed above the level of the liquid in the bath so that a layer of insulating material deposited on the wire from said liquid terminates short of the ends of the wire, suspending the wire in a second bath or baths with a greater part of the length of the wire adjacent each end being exposed above the level of the second liquid or liquids so that a layer of conducting material deposited on the insulating layer terminates short of the insulating layer at each end, and then suspending the wire again in the first bath and second bath or baths successively, with still greater lengths of the wire adjacent each end thereof being exposed above the liquid level during each successive deposition step so that each layer deposited on the preceding layer terminates short of that preceding layer.

An alternative method of producing a transformer according to said first aspect of the present invention comprises covering the whole length of the conductor wire with a plurality of alternately insulating and conducting layers, and subsequently removing selected end parts of each layer so that at each of its ends each layer terminates short of the immediately underlying layer and the insulating layer in contact with the conductor wire terminates short of that wire at each end. An advantage of this alternative method is that it facilitates the additional removal of selected intermediate parts of some of said layers, when such removal is desired.

Some embodiments of the present invention will now be described by way of example, with reference to the accompanying drawings, in which:

Fig. 1 shows an axial section through part of a layer-covered conductor wire,

Figs. 2 and 3 show transformers comprising the layer-covered wire of Fig. 1,

Fig. 4 is a schematic representation of a method of producing a transformer,

Fig. 5 shows an axial section through part of a second layer-covered conductor wire, and

Figs. 6*a* and 6*b* together schematically

[*Price 4s. 6d.*]

represent an alternative method of producing a transformer.

Referring first to Fig. 1, a central conductor wire 1 is provided with an insulating layer 2, a conducting layer 3, another insulating layer 4, and another conducting layer 5. The wire 1 and the layers 3 and 5 are preferably of copper, and the layers 2 and 4 are preferably of a cellulose lacquer. In practice the thickness of the layers 2 to 5 is very much smaller than the diameter of the conductor wire 1, and in the drawings the thickness of these layers has been exaggerated for the sake of clarity.

It will be seen from Fig. 1 that the lengths of the respective layers 2 to 5 are such that the layer 2 terminates short of the ends of the wire 1 and each succeeding layer terminates short of the ends of the layer which precedes it. The result of this stepped formation is that the ends of the wire 1 and of each of the conducting layers 3 and 5 are exposed to facilitate the fixing (preferably by soldering) of electrical connections thereto.

Such connections are shown in Fig. 2, where the conductor wire 1 is to be used as the primary circuit of the transformer, the outer conducting layer 5 is to be used as the secondary circuit, and the intermediate conducting layer 3 is to constitute an electrostatic screen. Wires *1a* and *1b* are soldered to the ends of the wire 1 to feed the primary current thereto. Wires *5a* and *5b* are soldered to the ends of the layer 5, and a centre tapping is effected by soldering a wire *5c* to the layer 5 substantially midway of its length. The layer 3 is earthed by a single wire *3a* since it is to function as an electrostatic screen. With this arrangement the transformer ratio is equal to 1 if the output tappings *5a* and *5b* are used, and is less than 1 if the tappings *5a* and *5c* or *5b* and *5c* are used. The roles of the conductor wire 1 and the layer 5 can naturally be reversed, in which case a transformer ratio greater than 1 is obtained.

It will be seen that in Fig. 2 the layer-covered wire 1 is disposed in coiled formation and constitutes a core-less transformer. Fig. 2 is intended principally to show the disposition of the layer covered conductor wire and it is to be understood that the Figure does not accurately illustrate the relationship in practice between the diameter of the layer-covered wire and the diameter of the various loops in the coil. Moreover in practice the coils would probably comprise more than five loops.

Fig. 3 shows a cored transformer obtained by passing the layer-covered wire of Fig. 1 through a ferrite cylinder 10. It will be observed that in this embodiment the transformer has two secondary circuits, since both the conducting layers 3 and 5 are provided with terminal output wires *3a*, *3b* and *5a*, *5b* respectively.

Fig. 4 is a schematic representation of a method of producing the layer-covered wire of Fig. 1. In this method the copper conductor wire 1 is first coiled over part of its length in order to avoid variations in shape which can result from the manipulation of a wire already covered with layers. The wire 1 is then suspended by its ends 11 and 12 from a platform 13 and is subsequently plunged successively into an etching bath 14, a bath 15 of cellulose lacquer for deposition of the insulating layer 2, and a series of chemical or electrolytic baths such as 16 and 17 for the formation of the copper layer 3. It is then plunged once more into the bath 15 and the baths 16, 17 for the formation of the layers 4 and 5. Each time that a new layer is deposited, a greater length of the wire adjacent each end thereof is exposed above the surface of the liquid in the bath in question, so that the first deposited layer (2) terminates short of the wire 1 at each end and each succeeding layer 3, 4 and 5 terminates short of the one before it. When all the layers have been deposited the required electrical connections are soldered to the conducting layers, as shown by way of example in Figs. 2 and 3.

With the layer-covered wire of Fig. 1 it is possible to solder an electrical connection to the outermost layer 5 at any point along the length of the latter (as in the case of the centre tapping *5c* in Fig. 2) but such connections can be soldered only to the end portions of the layer 3 and conductor wire 1 since they are the only portions of that layer and wire which are exposed. Sometimes, however, (for example in the case of a transformer having several centre-tapped secondary circuits) it is necessary to have access to intermediate points on the wire 1 or to such points on a layer which is not the outermost layer.

An example of this is shown in Fig. 5 where the copper conductor wire 1 is covered with layers 2 to 9, the even-numbered layers being of insulating material such as cellulose lacquer and the odd-numbered layers being conducting layers of copper. The conducting layers 5 and 9 constitute secondary circuits, having centre-tapping connections represented by wires *5c* and *9c* respectively, and the conducting layers 3 and 7 constitute electrostatic screens. Since intermediate parts of the layers 9 and 7 have been removed to allow the the centre-tapping to be effected, wires *9d* and *7d* are provided in order to ensure the electrical continuity of those layers.

Figs. *6a* and *6b* schematically illustrate a method by means of which selected parts of various layers can be removed from an initially totally covered wire 1 in order to allow both end- and centre-tappings to be effected, as in the construction shown in Fig. 5. The part of the process represented by Fig. *6b* is an immediate continuation of the part illustrated in Fig. *6a*.

The method comprises passing the layer-covered wire through a series of tanks containing appropriate liquid baths and through a

number of sleeves the function of which will be described later herein. The wire passes through apertures provided in the walls of the tanks, and liquid which escapes through those apertures is collected and pumped back to the appropriate tank.

The element (indicated at F in Figs. 6*a* and 6*b*) which is subjected to this process comprises a central conductor wire initially covered troughout its length with alternately insulating and conducting layers as already described. The element F is successively passed through:

—a bath 20 comprising a solution of a photosensitive product capable of being rendered insoluble in water by exposure to intense light or to ultravoilet rays. Such a product can be constituted, for example, by a mixture of polyvinyl alcohol solution and an ammonium bichromate solution.

—an opaque sleeve 21 having a translucent part 21*a* of small length; an arc lamp 22 projects on to the part 21*a* a luminous beam rich in ultraviolet rays to render insoluble the photosensitive layer deposited by the liquid of the bath 20; the lamp 22 is switched off during the intervals of time corresponding to the passage of those parts of the element F from which the external layer 9 must subsequently be removed; the operation of the lamp 22 is synchronized with the drive mechanism for the element F; this synchronization being obtainable by means well known in the art, the synchronization devices will not be described.

—a tepid water bath 23 to dissolve the layer of photosensitive product coming from the bath 20 at those parts where it has not be subjected to the action of the arc lamp 22.

—an acid bath 24 to dissolve the copper layer 9 at the places where the layer of photosensitive product has been removed by the bath 23.

—a bath 25 resembling the bath 20.

—a sleeve 26 resembling the sleeve 21 and lit by an arc lamp 27 which is switched off during intervals of time corresponding to the passage through the translucent part 26*a* of those parts of the element F from which the insulating layer 8 must subsequently be removed.

—a tepid water bath 28 to dissolve the layer of photosensitive product which has not been exposed to the arc lamp 27.

—a methyl acetate bath 29 to dissolve the cellulose varnish layer 8 at the places where the photosensitive product has been removed by the bath 28.

—a bath or photosensitive product 30 resembling the baths 20 and 25.

—a sleeve 31, lit by an arc lamp 32 whose periods of extinction correspond to the length of the parts to be removed from the conducting layer 7.

—a series of baths and sleeves not shown in the Figures and successively comprising baths resembling 23, 24, 25, a sleeve resembling sleeve 21, baths resembling baths 28, 29, 30, a new sleeve resembling sleeve 21, and so on, the duration of extinction of the arcs associated with the sleeves growing smaller in a manner corresponding to the lengths of the parts which it is desired to remove from the layers 6, 5, 4, 3 and 2.

WHAT WE CLAIM IS:—

1. An electrical transformer comprising a conductor wire constituting a primary circuit of the transformer and covered by a plurality of alternately insulating and conducting layers, one of the conducting layers constituting a secondary circuit of the transformer and the length of the layers being such that the ends of the conductor wire and the ends of each conducting layer are exposed to facilitate the fixing of electrical connections thereto.

2. A transformer according to claim 1, wherein a conducting layer between the conductor wire and said one conducting layer constitutes an electrostatic screen.

3. A transformer according to claim 1 or claim 2, wherein said one conducting layer is additionally exposed at a point intermediate its ends to facilitate the fixing of an electrical connection to that exposed point.

4. A transformer according to any one of claims 1 to 3, additionally comprising a magnetic core.

5. A transformer according to any one of claims 1 to 4, wherein the layer-covered conductor wire is disposed in a coil formation.

6. A transformer according to any one of the preceding claims, wherein the conductor wire is a copper wire, each conducting layer is a layer of copper, and each insulating layer is a layer of cellulose lacquer.

7. An electrical transformer substantially as herein described.

8. An electrical transformer substantially as herein described with reference to Fig. 1, Fig. 2, Fig. 3 or Fig. 5 of the accompanying drawings.

9. A method of producing a transformer according to claim 1, comprising suspending the conductor wire in a first bath with the ends of the wire exposed above the level of the liquid in the bath so that a layer of insulating material deposited on the wire from said liquid terminates short of the ends of the wire, suspending the wire in a second bath or baths with a greater part of the length of the wire adjacent each end being exposed above the level of the second liquid or liquids so that a layer of conducting material deposited on the insulating layer terminates short of the insulating layer at each end, and then suspending the wire again in the first bath and second bath or baths successively, with still greater lengths of the wire adjacent each end thereof being exposed above the liquid level during each successive deposition step so that each layer deposited on the preceding layer termi-

nates short of that preceding layer.

10. A method according to claim 9 wherein the conductor wire is subjected to an etching step before it is suspended in said first bath for the first time.

11. A method according to claim 9 or claim 10, wherein the conductor wire is coiled over part of its length before it is suspended in said first bath for the first time.

12. A method according to claim 9, substantially as herein described.

13. A method according to claim 9, substantially as herein described with reference to Fig. 4 of the accompanying drawings.

14. A method of producing a transformer according to claim 1, comprising covering the whole length of the conductor wire with a plurality of alternately insulating and conducting layers, and subsequently removed selected end parts of each layer so that at each of its ends each layer terminates short of the immediately underlying layer and the insulating layer in contact with the conductor wire terminates short of that wire at each end.

15. A method according to claim 14, wherein selected intermediate parts of some of said layers are also removed.

16. A method according to claim 14 or claim 15, wherein said selected parts removed by being dissolved in baths of appropriate liquids, the remaining parts of the layers being provided with a coating which is resistant to the action of those liquids.

17. A method according to claim 14, substantially as herein described.

18. A method according to claim 14, substantially as herein described with reference to Figs. *6a* and *6b* of the accompanying drawings.

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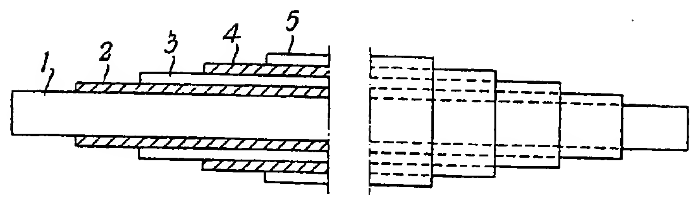

FIG.1

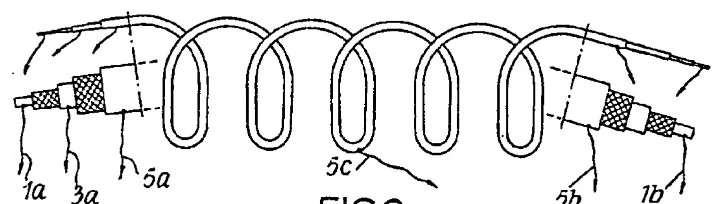

FIG.2

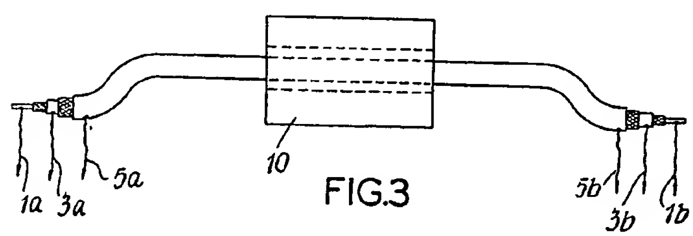

FIG.3

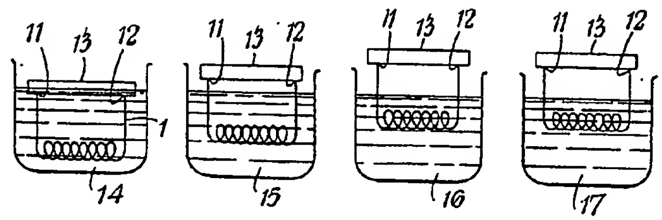

FIG.4

1053337 COMPLETE SPECIFICATION

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Sheets 1 & 2

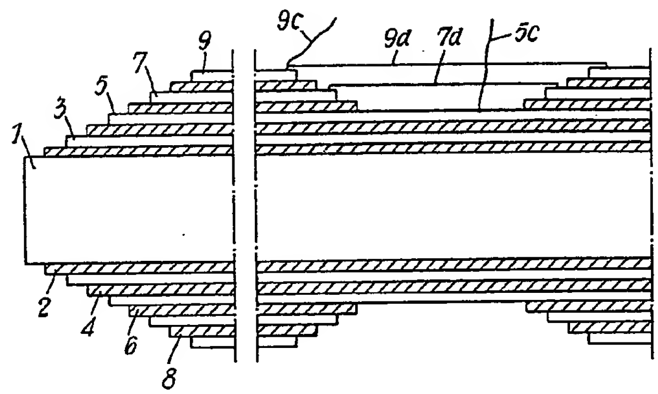

FIG5

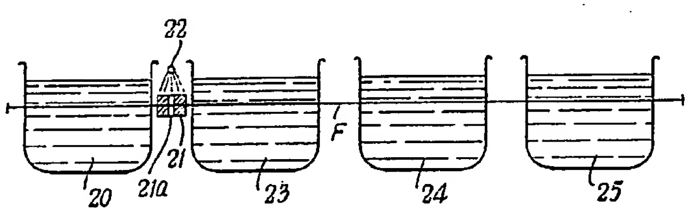

FIG.6a

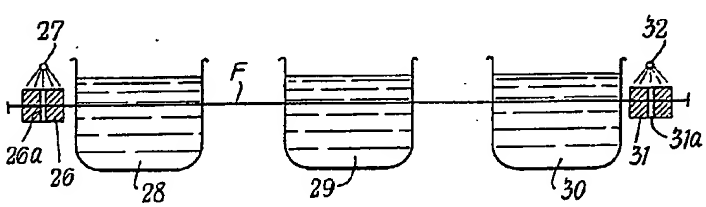

FIG.6b

1053337 COMPLETE SPECIFICATION

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Sheets 1 & 2

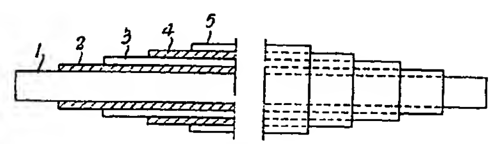

FIG.1

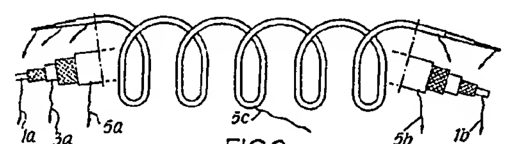

FIG.2

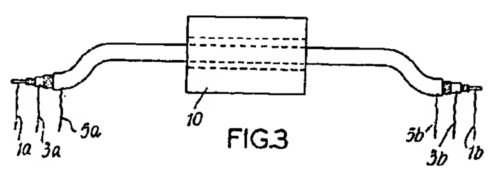

FIG.3

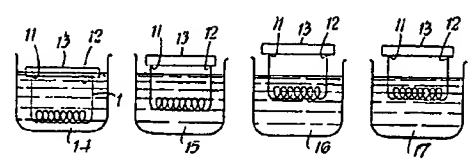

FIG.4

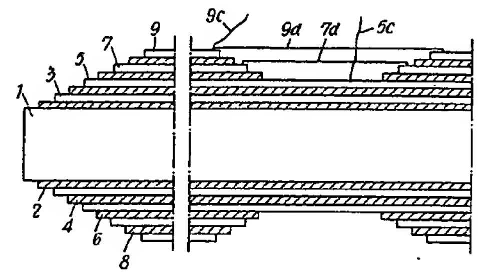

FIG5

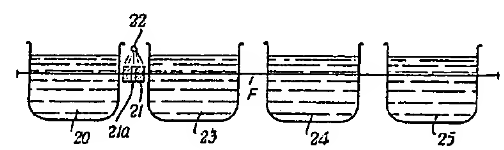

FIG.6a

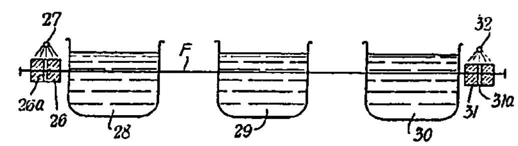

FIG.6b